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Highly efficient photonic nanowire single-photon sources for quantum information applications

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Within the emerging field of optical quantum information processing, the current challenge is to construct the basic building blocks for the quantum computing and communication systems. A key component is the single-photon source (SPS) capable of emitting single photons on demand. Ideally, the SPS must feature near-unity efficiency, where the efficiency is defined as the number of detected photons per trigger, the probability $g^{(2)}(\tau=0)$ of multi-photon emission events should be 0 and the emitted photons are required to be indistinguishable.

An optically or electrically triggered quantum light emitter, e.g. a nitrogen-vacancy center or a semiconductor quantum dot (QD), embedded in a solid-state semiconductor host material appears as an attractive platform for generating such single photons. However, for a QD in bulk material, the large index contrast at the semiconductor-air interface leads to a collection efficiency of only 1-2 %, and efficient light extraction thus poses a major challenge in SPS engineering.

Initial efforts to improve the efficiency have exploited cavity quantum electrodynamics (cQED) to efficiently couple the emitted photons to the optical cavity mode. An alternative approach based on QDs in a photonic nanowire (Fig. 1a) was recently proposed, and the first experimental demonstration featured an efficiency of 0.72. [1] This geometry does not employ a cavity but instead relies on a geometrical screening effect to efficiently couple the emitted photons to the optical mode of interest. [2] The photonic nanowire “trumpet” design based on an inverted taper and compatible with metal contacts, shown in Fig. 1(b), very recently resulted in an efficiency of 0.75 under optical pumping. [3]

These designs do not employ a cavity and do not rely on resonant cQED effects to ensure a high β factor, meaning that efficient coupling from the QD to the guided mode is obtained over a broad spectral range of ~ 50-100 nm. [4] This means that spectral alignment between the emitter line and a narrow cavity line is not required, which represents a huge practical advantage in the fabrication. Furthermore, for a given dot density, the smaller area of the nanowire QD layer compared to that of e.g. micropillars means that fewer dots are present, and very pure photon emission with a measured $g^{(2)}(\tau=0)$ as low as 0.008 [1] has been obtained.

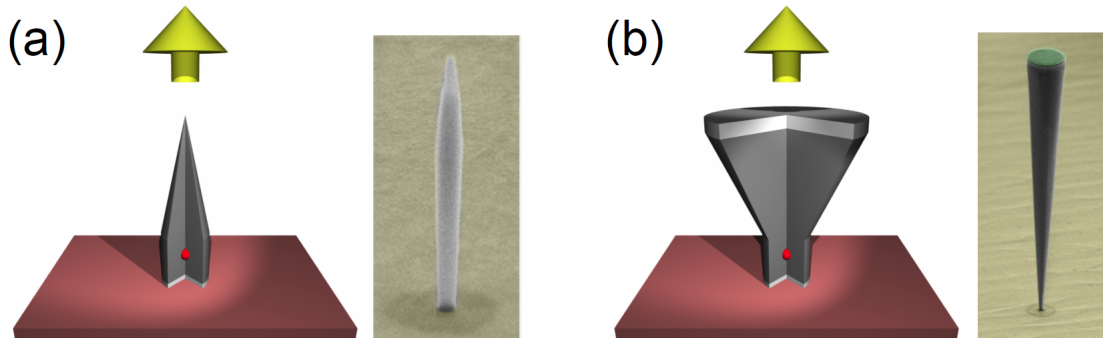


Fig. 1. Schematics and scanning electron micrographs of photonic nanowire single-photon sources based on a regular (a) and an inverted (b) conical tapering.

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